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STUDY OF MESOSCALE EXCHANGE
PROCESSES UTILIZING LANDSAT
AIR MASS CLOUD IMAGERY

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PREFACE AND SUMMARY

Small scale cumulus associated with both tropical and polar air masses over the central United States as observed in LANDSAT images are being analyzed. The objective of the analyses is to define relationships between the spacing and density of the cumuliform cloudiness and major terms of the surface energy and water budgets.

A visual analysis of cloud cover and albedo on two of the three LANDSAT images selected yielded a weak relationship between high albedo and high cumulus concentration.

LANDSAT CCT's have been received for the selected cases, although no data have been received from the ground truth test sites. Climatological data from cooperative climatological stations have been collected and punched on computer cards.

Computer algorithms necessary to read and printout selected portions of CCT's are being developed. An algorithm to translate calibrated voltage counts into albedo is being developed and is almost completed. Algorithms have also been prepared to calculate the heat and moisture budget of the surface from available climatological observations.

1.0 WORK ACCOMPLISHED DURING THIS PERIOD

1.1 Selection of Case Studies

A total of five potential case studies have been selected and CCT's have been ordered and received for these. Nevertheless, surface heat and moisture budgets will be calculated for only two of these cases. The other cases will be used in a back-up mode in the event insufficient climatological data may cause the exclusion of any of the two primary cases selected. Table 1 lists the five case studies in order of preference.

Table 1

Selected Occurrences of Cumuliform Clouds in LANDSAT Images

Scene ID	Area	Date	Air Mass
173615555	Illinois	29 July '74	CP
170416243	Texas	27 July '74	CP
170116024	Illinois	24 June '74	CP
131715363	Ohio	5 June '73	Modified CP
167016331	Kansas	24 May '74	MP & CP

1.2 Compilation of Climatological Data

Climatological data necessary for calculating surface heat and moisture budgets have been extracted from NOAA publications for the five cases, and about half of these data have been punched on cards.

The climatological data from cooperative climatological stations in the areas of interest include maximum and minimum temperatures, daily precipitation, dew point, wind, and cloud cover. Each of the five cases has from about 10 to 20 stations in the area of interest reporting daily maximum and minimum temperatures and precipitation, and one or two stations also reporting dew point, wind, and cloud cover.

1.3 Development of Computer Software for Calculating Heat and Moisture Budgets

Software that calculates the surface heat and moisture budget terms from daily climatological data has been assembled and tested. The principal subroutines employed are, 1) ETP which calculates the radiation terms of the heat budget, and the potential evaporation (ETP) by the Penman (1948) method, and, 2) SMBGT which calculates soil moisture contents of three soil layers and the actual evaporation, ET, by a method called the "Versatile Budget, VB." developed by Baier and Robertson (1966) and slightly modified by EarthSat.

1.4 Development of Software for Calculating Surface Albedo from MSS CCT's

Software is being written to estimate surface albedo according to the equation given on page 20 of the work proposal. The estimation of the albedo consists of three parts:

1) Calculation of vertical and slant-path transmissivities, $T_i(z)$ and $T_i(\theta)$, for the LANDSAT case in question.
2) Construction of a look-up table of MSS channel voltage count V_i versus channel radiance divided by zenith transmissivity $(N_i/T(z)_i)$.
3) Reading of CCT's and translation of voltage counts to albedoes, A, by

$$A = C \cdot \sum_1^4 \left(N_i / T_i(z) \right)$$

where $C = \pi / \cos\theta \left(\sum_1^4 H_i T_i(\theta) \right)^{-1}$

C is a constant for the specific case in question and is calculated in part (1). θ is solar elevation angle. H_i is solar radiance at top of atmosphere for MSS channels i = 1,2,3,4. The sequence of calculations is schematically illustrated in Figure 1.

The first part of the albedo estimation is accomplished by the TRANS SUBROUTINE, and requires as input solar elevation angle θ, solar radiances at top of atmosphere, H_i, and atmospheric water vapor.

The construction of the tables of Voltage counts vs. $N_i/T_i(z)$ greatly speeds up the albedo calculations. Additionally in the READ SUBROUTINE the MSS Voltage counts are sampled at specified intervals (every 10th value is sufficient), and values above a

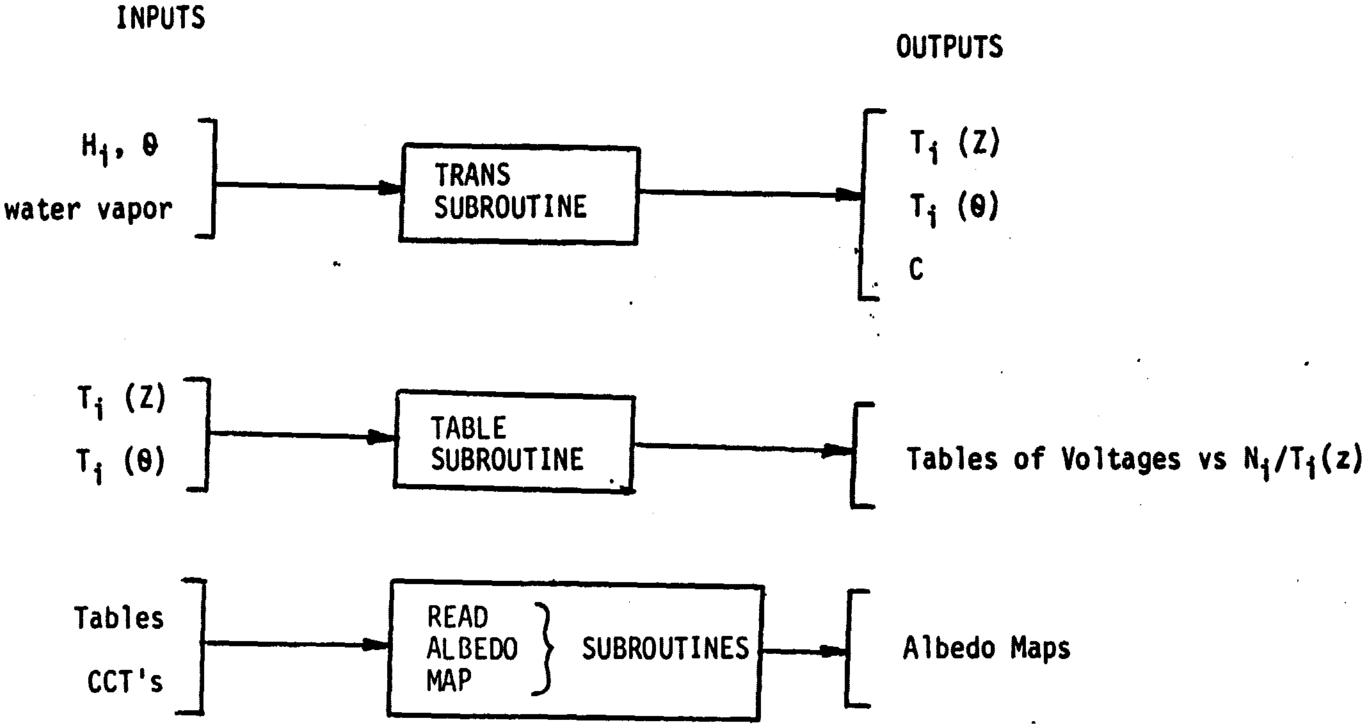

Figure 1

Input - Output of Software for Albedo Calculations

certain threshold typical of clouds are eliminated so that the data are representative of surface albedo. The sampling scheme keeps down computer time and assures an adequate sample number. An average albedo is then obtained for a 5 X 5 n. mile square and mapped in the MAP SUBROUTINE.

Presently, the TRANS, TABLE, ALBEDO SUBROUTINES are completed. The MAP SUBROUTINE is being written, and the READ SUBROUTINE is being modified to handle a variable sampling scheme.

1.5 Method of Calculating Atmospheric Transmittances for the MSS Channels

The total atmospheric transmittance for given absorber amounts and wavelength interval is calculated by the TRANS SUBROUTINE from transmittance tables derived graphically from charts presented by McClatchey et al. (1971). Briefly, the method consists first in determining the absorbers amounts in the required atmospheric path which are then used in conjunction with the transmittance charts to determine separately the transmittance due to: (1) molecular (line) absorption (H_2O, O_3, and the uniformly mixed gases), (2) molecular (continuum) absorption (H_2O, H_2), (3) molecular (Rayleigh) scattering, and (4) aerosol extinction (absorption and scattering) as a function of wavelength interval. The individual transmittances for each wavelength interval are multiplied together to obtain the total transmittance for the interval. The transmittance tables for SUBROUTINE TRANS were prepared for a wavelength interval of $\Delta\lambda = 0.1$ μm over the range of the MSS (0.5 - 1.1 μm). Table 2 is an example of a transmittance table (for water vapor) used in SUBROUTINE TRANS.

1.6 NOAA VHRR and VSSR Data

No VHRR surface temperature data are available from NOAA for the selected LANDSAT cases since these data are not archived. VSSR data are available but because of their lower resolution (5-15 miles) these would be contaminated by cloud cover and would not yield a true surface temperature. Therefore, we presently discard the idea of using VHRR (or VSSR) temperatures to aid us in "spreading out" the point calculations of the surface heat and moisture budget. We shall, nevertheless, consider surface albedo to aid us in the spatial distribution of the budget terms.

Table 2

Transmittance of Water Vapor

$\Delta\lambda$	cm of precipitable water					
	0.1	0.5	1	2	5	10
0.5-0.6	1.0	1.0	1.0	1.0	1.0	1.0
0.6-0.7	1.0	1.0	1.0	1.0	1.0	1.0
0.7-0.8	.983	.958	.922	.906	.865	.815
0.8-0.9	.984	.963	.932	.917	.873	.824
0.9-1.0	.902	.787	.716	.644	.591	.531
1.0-1.1	.947	.890	.856	.830	.778	.691

2.0 PROGRAM FOR NEXT REPORTING PERIOD

1) Completion of compilation of climatological data and gathering of soil type information needed for soil moisture calculation.

2) Completion of the MAP and READ SUBROUTINES.

3) Calculations of surface albedoes necessary for the heat budget will be performed for two selected cases.

4) Heat and moisture budgets calculations will be performea for two selected cases.

   Calculations will be done with climatological data from stations in areas (usually 10-20 stations), and for at least a week prior to the LANDSAT image up to the time of the image. This is necessary to estimate surface moisture available for evaporation at time of image.

   Heat and moisture budget terms will be spread out from the point calculations by taking into consideration the mapped surface albedoes.

5) We will begin looking at the spatial distribution of the budget terms and their relationships to the spatial distribution of cumulus clouds as seen in the LANDSAT images.

6) We shall continue to try to obtain corroborative data on evaporation and radiation from the cooperative test sites.

3.0 DATA USE

In the investigation to date we have the following data use summary.

1. Value of Data Allowed

Bulk	768
CCT	9600

2. Value of Data Ordered

Bulk	200
CCT	2400

3. Value of Data Received

Bulk	200
CCT	2200